Technical Memorandum

Soil Resource Evaluation Pilot Study
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(Construction Report and Evaluation)

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1. Introduction

This Technical Memorandum ("Memo") documents the *Soil Resource Evaluation Pilot Study* activities performed as the subsequent effort to the *Soil Resource Evaluation System* (SRE) developed by UC Davis. This Memo has been prepared with the input of Caltrans' representatives, Dr. Claassen of UC Davis, the landscape architect/contractor and project geotechnical consultant. This Memo provides summaries of the *SRE Pilot Study* objectives, test site selection, site descriptions, amended soil descriptions, construction activities, geotechnical observations, implementation costs and performance evaluations. In addition, suggested implementation strategies and guidelines for project construction techniques are provided for subsequent projects.

2. UC Davis' Soil Resource Evaluation System

This *SRE Pilot Study* project is the subsequent effort of the *Soil Resource Evaluation System* (SRE) developed at UC Davis. The *SRE System* is generally described as a soil regeneration process for erosion control and revegetation. Soil erosion/revegetation programs are considered an integral component of storm water pollution prevention efforts. The *SRE System* entailed a variety of field and laboratory studies with regards to erosion control and revegetation of drastically disturbed soils with native species. The *SRE System* is described in the document titled "*Soil Resource Evaluation*" (CTSW-RT-05-073.20.1) and, for one of the project sites, in a document titled *"Soil Resource Evaluation: Templin Hwy Revegetation"* draft dated February 18, 2008.

The *SRE System* lead researcher is Dr. Victor P. Claassen, Assistant Research Soil Scientist with the UC Davis Department of Land, Air and Water Resources. The subsequent effort of Dr. Claassen's studies was to directly apply the *SRE System* research to demonstration sites with disturbed slopes along Caltrans' highway corridors throughout the State. Dr. Claassen's evaluation of the subsequent effort is included in the document titled *"Soil Resource Evaluation II*" (preliminary draft, RTA#43A0168, Task Order 19).

For purposes of this Memo, this subsequent effort is called the *SRE Pilot Study* and is the "Project" discussed herein.

3. Project Objectives - SRE Pilot Study

The primary objectives of the *SRE Pilot Study* were to:

- Implement the UC Davis' *SRE System* at three demonstration sites.
- Document the implementation efforts, results and concerns at these sites.
- Develop strategies and guidelines for the implementation of the *SRE System* at future project sites throughout the State.

To accomplish the objectives of the *SRE Pilot Study*, demonstration sites were selected, and the existing site conditions were evaluated by the project team. The *SRE System* components were then tailored to each site, evaluated by the project team, and installed by the contractor. Following are more detailed summaries of the project activities for the *SRE Pilot Study*.

4. Site Selection

Several sites across the State were considered for potential inclusion in the *SRE Pilot Study*. In general, the potential sites were disturbed slopes that each had histories of soil erosion, poor vegetative growth and localized surficial failures. The potential sites were existing candidates for additional slope treatments to reduce soil erosion and help Caltrans meet current storm water pollution prevention guidelines. In addition, additional treatments would have likely reduced soil erosion maintenance efforts at the sites. The following potential sites were evaluated by the Project Team for inclusion in the *SRE Pilot Study*:

"*Clear Lake Site*" on Highway 20 at PM 46.0 in Lake County

"*Lotus Site*" on Highway 49 at PM 24-24.5 in El Dorado County

"*Templin Site*" Adjacent project site west side on Interstate 5 at PM65.4 in Los Angeles County

"*Miramar Site*" on State Route 78 at PM32.6 in San Diego County

"*San Diego Site*" on Interstate 15 at PM 22.5 in San Diego County

Ms. Finn, Caltrans Landscape Technical Specialists, determined that the slopes at all the potential sites were generally suitable for the *SRE Pilot Study*, however, the San Diego County sites were excluded due to environmental concerns and permit processing requirements.

5. Clear Lake Site

5.1 Summary of Existing Conditions

The "*Clear Lake Site*" is located at PM 46.0 on Highway 20 in Lake County. The site consists of a generally south-facing cut slope excavated during widening of this section of the highway in 2004. The slope is located along the northern side of the highway (*see Photo 1*). The slope is approximately 330 feet long, attains a maximum height of approximately 80 feet, with a maximum slope inclination of approximately 2 to 1 (horizontal to vertical). Vegetation efforts subsequent to excavation of this slope have been deemed generally ineffective. The slope-face soils experienced minimal plant germination, indications of down slope soil erosion, and two fairly distinct areas of surficial slumping. Desiccation cracks were observed in the upper portion of the cut slope and the adjacent upslope area. Some of the cracks exceeded one foot in depth into the onsite clayey soils. The cut slope is at the toe of a natural ridge that ascends northerly onto adjacent properties. It appears that runoff of surficial waters from the adjacent properties discharged over the excavated slope and may have contributed to formation of the shallow soil slip problems at the *Clear Lake Site*.

5.1.1 Summary of Geotechnical Conditions

Observations of the exposed geologic/soils conditions were made by the project geotechnical consultant for the *Clear Lake Site*. Geotechnical documentation regarding the existing cut slope and road widening project had been requested from Caltrans but was not available at that time for review. Based on limited surficial observations and review of a geologic map of the area, the geotechnical consultant concluded that the slope appears to be underlain by a Cretaceous sedimentary bedrock unit, primarily consisting of shale (i.e. claystone and siltstone). Measurements of the geologic attitude (strike/dip) of the shale indicate that the dip of the shale is generally “out of slope”, which is a factor that may contribute to slope instability.

The geotechnical consultant observed that a clayey, natural soil has developed on and is gradational with the underlying shale. The depth of the natural soil horizon appears variable across the slope. Based on visual and textural evaluations the onsite soils appeared to be clay-rich. Based on observations of the clayey soils and laboratory testing (ASTM D4829) of one soil sample, the onsite soils have an expansion potential ranging from medium to very high. Expansive soils typically increase in volume with the introduction and absorption of water, and they decrease in volume with the evaporation and dissipation of water. Desiccation cracks are typically a result of this process. Desiccation cracks were observed in the upper portion of the cut slope and the adjacent upslope area. Some of the cracks exceeded one foot in depth into the onsite clayey soils. The geotechnical consultant also observed the two areas of surficial slumping and indications suggestive of downslope “creep” of the clayey soils.

The cut slope is at the toe of a natural ridge that ascends northerly onto adjacent properties. It appears that runoff of surficial waters from the adjacent properties discharged over the excavated slope and may have contributed to the formation of the soil slip problems at the *Clear Lake Site*.

5.2 Initial SRE Construction Concept – Clear Lake Site

The Clear Lake site was chosen because it represented typical roadside slope erosion and vegetation problem type projects which have long term maintenance and liability problems for Caltrans. The 2:1 slope face at this field site was observed 1) to have limited native plant growth; 2) be covered with a surface layer of expansive clay soils that would seal when wet; 3) have little surface erosion (gullies) but several areas with large shallow slips. Therefore, the initial *SRE System* construction concept for the *Clear Lake Site* was to improve the soil conditions for growing plants and to reduce storm water runoff using soil-based treatments and to add geotechnical stability to the site by removing the existing surficial slope failure areas and intercepting the interface plane of the shallow slips. The strategies developed by Dr. Claassen included addressing slope run-on, restricted infiltration and modifying the existing soil profile with the incorporation of organics with the goal of improving the growing condition for sustainable native perennial plant material and reduce storm water runoff. The proposed strategy included:

- Addressing slope run-on
- Incorporation of organics in the upper 12 inches to enhance water infiltration, and to increase rooting depths.
- Deeper tillage over some portions of the slope to increase the potential for deeper rooting depths and enhance infiltration to sustain plants over dry periods
- Incorporation of organics into the soil profile that include screened compost, that adds nutrients, organic matter and increases water holding capacity; and shredded green waste material that provides long-term nutrient infiltration.

Several alternative methods to accomplish these goals were proposed and called “bench version”, “step version”, “rip version” and “slot-rip version”. Details of this *SRE System* concept plan were developed by Dr. Claassen which generally included the proposed incorporation of compost into the upper one foot of the existing slope face with deeper tillage for incorporation of organics into the upper three feet of the slope face. An amendment mixture of 50 percent mulch with 50 percent compost was proposed for this project based on the project soils report.

5.2.1 Geotechnical Concerns Regarding Initial SRE Construction Concept

The geotechnical consultant understood that the intent of the *SRE Pilot Study* was to apply the UC Davis’ *SRE System* to the slope. The intent of this action would be to help reduce soil erosion and revegetate the slope with native species. It was stressed to the geotechnical consultant and landscape architect/contractor by the Caltrans project manager and Dr. Claassen that this was a research project which needed to address both geotechnical and biological approaches and would not necessarily incorporate typical engineering solutions to solve the surficial slope stability and soil erosion concerns such as compaction.. The goal for this project was to incorporate the *SRE Pilot Study* goals and objective as much as site geotechnical conditions allowed.

The primary geotechnical concerns related to the implementation of the initial construction revegetation concepts at the *Clear Lake Site* generally included the following items related to slope stability:

- Out-of-slope geologic bedding and potential for negative impact by proposed construction schemes. Outward sloping bedding planes promote slips when saturated.

- Placement of a “blanket” of loosely compacted, organics-amended soils on a cut slope without typical benching or compactive efforts. A surface “blanket” of porus, loose material can fill with water and liquefy and slip downslope.

- Existing slumping of surficial soils and potential for future slumps or slope failures. The existing slope already shows signs of lateral, downslope movement during the previous winter.

- Drainage of offsite surface waters onto the slope face and associated erosion problems

The existing site conditions and geotechnical concerns were incorporated into the SRE construction concept. Based on field discussions, the geotechnical consultant, Dr. Claassen and the landscape architect/contractor developed a modified construction plan that was adapted to the existing site conditions and still attempted to meet the *SRE Pilot Study* project objectives at the *Clear Lake Site*. Where applicable, the geotechnical recommendations for each step of the field implementation sequence are summarized in Section 5.4.

5.3 Amended Soil Descriptions – Clear Lake Site

The following are the descriptions of the amended soil materials and seed mix used during SRE Pilot Study construction activities at this site. These terms as described below are used exclusively in subsequent sections for this Clear Lake Site and should not be considered applicable to the other SRE Pilot Study sites. As per the project-specific Project SRE Report specified mulch and compost was be placed and incorporated into the soil profile as directed. Incorporation of organic amendments such as yard waste compost provides easier rooting after incorporation and provides a blend of nutrients for a wide range of soil and plant growth conditions. Addition of woody mulch material applied to soil surface assists in erosion control, increased water infiltration into the soil substrate and provides a protective cover for plant establishment.

As per the Project SRE Report a typical blend of 50:50 yard waste compost (screened to 10mm (3/8 inch minus) and woody shred mulch material was applied to the project surface then incorporated and mixed into the soil profiled to a depth of 10 inches to provide an available source of nutrients for plant establishment and an assessable soil substrate for easy deep root establishment.

> "Compost" Garden Humus at this site generally consisted of fine compost (3/8 minus) 75 % composted overs (3 to 6 inches in length) that have been processed through a float tank to remove metal and glass "unscreened yard waste compost" supplied by Napa Recycling.
>
> "Mulch" used at this site generally consisted of "wood shred mulch" supplied by Napa Recycling.
>
> The "native seed mix" at this site generally consisted of native grasses and shrubs (see seed mix below)

Lake County Site

<u>Seed Mix</u>

Species	***PLS WT/Acre***
1. Achillea millefolium	1.0
2. Eriophyllum lanatum	2.0
3. Lupinus bicolor	5.0
4. Elymus multisetus	2.0
5. Elymus glaucus	8.0
6. Nassella pulchra	5.0
7. Poa sccunda	2.0
8. Melica californica	6.0
9. Lotus purshianus	2.0

5.4 SRE Field Implementation Sequence

Discussions between the project team members about the actual field conditions, geotechnical concerns, construction equipment limitations, and possible effective construction techniques resulted in development of the implemented construction concept. Following is a summary of the actual field tasks that were performed at the *Clear Lake Site*.

5.4.1 Clearing and Grubbing

The *Clear Lake Site* was cleared of invasive weeds and grasses by hand pulling and excavation with hand tools. Some of the grasses were also mechanically trimmed down to the ground surface.

5.4.2 Construction Steps - Amendment Incorporation

To distribute the amendments to be incorporated across and into the slope, the surface of the *Clear Lake Site* slope area was initially covered with a 3-inch thick blanket of these amendments. The amendments consisted of a 1.5-inch thickness of compost and a 1.5-inch thickness of woody shred materials (as described in Sections 5.2 and 5.3). These amendments were eventually incorporated into the onsite soils up to a depth of approximately 4 feet utilizing the following techniques:

a. Contour Rip Method: A Caterpillar D-6 track dozer with 36-inch long ripping teeth was initially used to rip the onsite soils and incorporate amendments into the soils. The ripping pattern generally consisted of equipment passes approximately 3 feet apart, roughly parallel to the toe of the slope (*see photo 2)*. This method incorporated some amendments into the soil but not as effectively as desired by the project team members. In particular, the organics materials did not get mixed more than 18 to 24 inches into the soil and the lateral movement of loose soil caused by crabbing of the tractor created uneven distribution of loose organics into the soil profile. Therefore, additional treatments were developed on site.

b. Bench Fill Method: During the *Amendment Incorporation* steps as described in this Section 5.4.2.c, the geotechnical consultant recommended that the interface between the amended soils and underlying natural soils should not be parallel to the existing slope face so that a slip plane was not created that would easily fail. Therefore, the base of the volumes with incorporated amendments should rest on a horizontal base, resulting in an undulating interface that is keyed into the undisturbed slope material. To address this recommendation, an additional method of incorporation was developed that consisted of a D-6 dozer that passes, roughly perpendicular to the toe of the slope, traveling vertically up-slope The dozer excavated the soil surface in an undulating manner by raising and lowering the blade as the dozer progressed up the slope face. The resultant excavated slope areas were approximately 2 to 3 feet deep and were spaced approximately 8 to 10 feet apart vertically on the slope surface. This method thoroughly mixed and incorporated the amendments into the soil profile to the recommended 3 foot depth as desired by the project team. During the descents, the dozer lowered its blade and smoothed the slope surface back to its original configuration. The descents also resulted in additional mixing of the amendments into the soil. This technique resulted in a high degree of amendment incorporation acceptable to the project team. This technique is shown on *Photo 3*. This method represents the "bench" method in which the tilled or mixed materials rest on a more or less horizontal bench to resist lateral movement when wet.

c. The slope face was subsequently track-walked one time passing up and down the slope by the D-6 dozer to recompact the surficial soils to a minimum level generally acceptable to the geotechnical consultant, considering the intent of the initial construction concept for this site as outlined in Section 5.2.

   The geotechnical consultant used a soil probe to judge a minimum acceptable level of compaction for this project test study. This judgment estimate was unquantified and was based on professional experience. This probing indicated that the organics-amended soils were compacted at an estimated 80-85 percent compaction less than the typical minimum of 90 percent relative compaction (ASTM D1557) desired for fill soils.

   After the initial incorporation of the compost using the above methods the project team decided to test two additional soil profile amendment incorporation techniques to test alternative amendment incorporation techniques for specific localized areas. These additional techniques were added to test techniques that provided deep cracking of the soil profile and deeper incorporation of soil amendments into the soil profile needed to improve storm water infiltration and better plant rooting depths.

5.4.3 Construction Steps – Additional Soil Profile Modifications

Two additional soil profile modification efforts were performed at the *Clear Lake Site*.

Step Fill Method: The first additional modification technique used a track excavator with a 3-foot wide bucket to excavate pits that disturbed the existing in-place soils and incorporate additional amendments. These pits were approximately 6 feet wide and 4 feet deep. The excavated soil was amended with compost and mulch, replaced back into the hole and the slope surface was restored and recompacted using the excavator bucket to tamp the soil back in place. These pits were spaced approximately 15 to 20 feet apart in random patterns across the slope face. The base of these excavated and replaced volumes was more or less horizontal to resist lateral movement of the soil volume down slope. Because the bases of these excavated areas are spread individually across the slope, this method is called a "step" method, although the slope surface is still planar. On less stable slopes, these filled steps can be spread widely across the slope to provide scattered areas of infiltration and vegetative cover, without generating a uniform, disturbed "blanket" slope treatment.

a. Hammer Fracture Method: The second modification technique used the same track excavator with an impact breaker attachment to create impact holes in the existing in-place soils by fracturing localized areas on the slope. The resultant impact holes were approximately 1 foot wide and 2.5 to 3 feet deep. Fracturing of the clayey soils occurred adjacent to the impact points and extended approximately 3 feet laterally in all directions from the initial impact hole. In this case, no soil was excavated and replaced; but rather, the underlying geological materials were fractured and left in place.

During these *Additional Soil Profile Modification* efforts the geotechnical consultant recommended to limit the spacing of these pits such that a continuous interface between the disturbed soils and underlying undisturbed soils was not developed as not to create a slip plane and also this interface was not parallel to the existing slope face (to reduce the development of a potential failure surface). Intervening areas of generally undisturbed slope-face soils were desired by the geotechnical consultant. Therefore, it was agreed by the team to limit larger 4' by 6' pits to a minimum spacing of 15 feet apart and to be randomly spaced. It was also suggested by the project team for the impact holes to be a minimum of 5 feet apart in random spacing and clusters.

5.4.4 Stabilization of Surficial Slumps

Two areas of surficial slumps were observed on the slope face at the *Clear Lake Site* (*see Photo 1*). Three exploratory pits were excavated into these slumps so the geotechnical consultant could observe the failure surface and its depth. The interface between undisturbed soils and slumped soils was observed. This interface, the failure surface, was generally dipping out of slope and generally paralleled the bedding of the onsite shale. The failure surface extended to a maximum depth of approximately 3 feet in the main mass of the slumps.

To stabilize these slump areas and restore the slope face configuration, a repair scheme was proposed by the geotechnical consultant in the field. The stabilization method consisted of the excavation of two roughly horizontal benches across the slumps, one near the toe and one near the top of the slumps. The benches were excavated to a depth that disrupted the failure surface, and extended into the underlying undisturbed soils. The excavated soils were then replaced, moisture-conditioned, placed in lifts, and recompacted as fill on these benches. The repaired slope face was track-walked to recompact the surficial soils to a minimum level acceptable to the geotechnical consultant.

The geotechnical consultant also suggested that four additional horizontal benches be excavated across the project slope face. These benches would be an attempt to reduce the potential for future surficial slumping by disrupting the out-of-slope bedding planes that were similar to those that had previously failed. The soils on these benches were removed and recompacted to a minimum level acceptable to the geotechnical consultant (using a soil probe). These benches were roughly 25 feet long, 2 feet wide and 4 feet deep.

5.4.5 Control of Offsite Surface Waters

Storm water runoff from the adjacent upslope properties appeared to discharge over the *Clear Lake Site* cut slope. It was the opinion of the geotechnical consultant that this runoff on the slope face may have contributed to previous soil slippage and erosion problems at the site. The project team reviewed these site conditions and suggested adding a drainage channel at the top of the cut slope to intercept this surface flow and reduce offsite water influence on the site. This drainage channel was approximately 8 feet wide and 3.5 feet deep. This drainage channel was lined with permeable filter fabric and filled with dissipater-sized drainage rocks. This channel was connected to the existing drainage discharge facilities system at the site and diverted most of the offsite surface water around project test site (*see photo 4*). While this surface drainage system diverted surface water runoff off the site, subsurface flow would still occur through the permeable channel liner.

5.4.6 Landscape Installation

The final field activities at the *Clear Lake Site* included landscaping of the slope face. Landscaping included the application of hydroseeding with the native seed mix described in Section 5.3. Subsequently, the slope was top dressed with an approximately 2-inch blanket of mixed mulch and compost topped with a layer of rice straw. This blanket was applied to protect the hydroseed mix, promote water infiltration, reduce storm water runoff and to help retain soil moisture during plant establishment.

The project team also decided to test additional surface erosion control devices. Jute netting was installed on an approximately 60-foot wide section of the slope to test the potential added benefits of this additional erosion control application. Also eight-inch thick straw wattles were placed parallel to the slope at 15-foot spacing on the slope face for added surface erosion control during plant establishment.

5.5 Geotechnical Comments

The geotechnical consultant understood that the intent of the *SRE Pilot Study* was to apply the UC Davis' *SRE System* to the slope. The intent of this action was to demonstrate soil-based treatments that would help reduce soil erosion and revegetate the slope with native species.

Observations of the exposed geologic/soils conditions were made by the project geotechnical consultant for the *Clear Lake Site*. Geotechnical documentation regarding the existing cut slope and road widening project had been requested from Caltrans but was not provided for review.

The geotechnical consultant observed that a clayey, natural soil has developed on and is gradational with the underlying shale. This soil consisted mainly of disintegrated mudstones and siltstones with little or no natural soil aggregation, structural development or horizonation. The depth of the natural soil horizon appears variable across the slope. Based on visual and textural evaluations the onsite soils appeared to be clay-rich. Expansive substrates soils typically increase in volume with the introduction and absorption of water, and they decrease in volume with the evaporation and dissipation of water. Desiccation cracks are typically a result of this process. The desiccation cracks observed prior to the *SRE Pilot Study* activities were disrupted and destroyed, however, desiccation cracks may re-appear in the clayey soils. An advantage of the desiccation cracks in the *SRE Pilot Study* is their potential as an avenue for water to reach deeper rooting depths. A disadvantage is the introduction of water into poorly-compacted slope-face soils and their potential for their surficial slumping when saturated.

During the *SRE Pilot Study* construction steps, the geotechnical consultant had recommended that the interface between the amended substrates and underlying natural geologic materials soils should not be parallel to the existing slope face. It appears that the construction steps resulted in an undulating interface, which should reduce the potential for surficial slope instability. The pits and fractured areas disturbed the soils on the slope but the spacing of these pits was such that a continuous interface between the disturbed soils and underlying undisturbed soils was not developed and this interface was not parallel to the existing slope face.

The slope face was track-walked subsequent to amendment incorporation (as discussed in Section 5.4.2.d) to a minimum level generally acceptable to the geotechnical consultant. Typically, fill soils are compacted to a minimum relative compaction of 90 percent, based on laboratory standard ASTM D1557. In addition, geotechnical consultants typically recommend that organic matter be screened from fill substrates. Based on discussions with the project team, these two factors would have likely inhibited the intent of the *SRE Pilot Study*. Therefore, the organics-amended fill soils were placed and compacted to a level less than 90 percent relative compaction. The geotechnical consultant used a soil probe to judge a minimum acceptable level of compaction. This judgment can not be appropriately quantified and was based on professional experience and site conditions estimated to be 85 percent relative compaction.

Some other site factors were considered by the geotechnical consultant such as the *Clear Lake Site* slope was not immediately adjacent to a travel lane or pedestrian pathway. Also a fairly wide shoulder was at the base of the slope and would be available for short-term accumulation of substrate debris that may move downslope as a result of compaction and poor infiltration. In addition, structures that could be potentially impacted by surficial slope failures did not exist at the top or base of the slope.

5.6 Clear Lake Site Construction Summary

The *Clear Lake Site* was the first of the three *SRE Pilot Study* demonstration sites to be constructed and took the longest to complete. Experimentation with different equipment and construction techniques was performed to evaluate which methods effectively incorporated amendments into the soil profile to the satisfaction of the project team and could be done in a production-type manner. In addition, this site included the construction of a drainage channel along the top of slope to reduce the negative effects of surface water flow onto the site from the adjacent offsite property. There were also two slope areas with surficial slumping which required stabilization during project construction activities.

During initial efforts, the project team performed a field evaluation of the existing site conditions which included pits excavated for geotechnical evaluation of the slope areas. Based on these field evaluations the project team recommended treatments that fulfilled both the existing *SRE objectives and geotechnical slope stability objectives.*

A general consensus of the project team was reached regarding a modified construction plan to attain project goals. Subsequently, the landscape architect/contractor proceeded under direction of the project team to install the project using a production-type construction operation method.

The overall construction process once developed was easily installed using typical road construction equipment. The construction process as detailed in section 5.4 provided an efficient production sequence to implement the proposed *SRE Program* that met the projects goals and objectives. However, obtaining the specific mulch and compost as outlined in the project SRE Program was troublesome and caused delays in the construction process and costs for shipping were higher that typical Caltrans projects. Also the much supplied by Napa Recycling had large amounts of plastics and trash which had to be removed by hand increasing labor costs.

The overall production sequence was relatively cost effective and could be easily installed as part of the initial roadway project or as a separate retrofit project. This process typically would increase standard Erosion Control Type "D" process labor approximately an additional 3-4 days per acre and adding an additional cost of 75 cents per square foot to the original typical construction operation cost.

5.7 Post-Installation Site Observation

The *Clear Lake Site* slope was observed on three subsequent occasions by the project landscape architect/contractor to observe project performance. Site visits occurred two months, four months and 8 months after substantial completion of the construction activities. A photo of the slope four months after completion is included as *Photo 5*.

During the site visit two months after the completion of the construction, the site was experiencing a great amount of rainfall. There were no apparent indications of storm water runoff or erosion on the slope. The previously-failed areas that had been repaired appeared stable with no indications of slope movement. It was also observed that the adjacent properties showed signs of water runoff and erosion from the same rain event. In addition, the drainage channel at the top of the slope was observed and appeared to be effectively intercepting the water runoff from the adjacent upslope property. However, the hydroseeded mix was germinating but at a relatively slow rate. The project surficial soil compaction was also tested by probing by the landscape architect and it appeared that the soil compaction had slightly increased since initial construction but was still at an acceptable level for the project test program concept. The landscape architect/contractor and geotechnical consultant concluded that the project was performing better than anticipated, with the project showing minimal to no soil erosion and surficial rilling and substantially reduced storm water runoff. The project site also had no signs of soil surface sluffing or slipping as previously feared.

At the four-month site review climate conditions had changed, the *Clear Lake Site* slope soils were dry and the weather was becoming seasonally warm. The slope appeared to be performing as intended and had no indications of storm water runoff or soil erosion. Limited manual excavations were performed into the slope face which indicated that the soil profile had improved moisture-holding capacity with adequate levels of moisture to properly sustain plant growth. It was also observed that the soils on the adjacent property were very dry, and there was little to no moisture apparent in the near-surface soil profile. On the project slope, it was observed that the germination of the hydroseeded mix was less than expected. Apparently, the thickness of the mulch top dressing and straw combination was excessive and may have limited or delayed the germination of the hydroseed mix. However, it was also observed that some of the germinated hydroseeded plant material had drastically improved rooting depths extending 5 to 6 inches into the soil profile. Previous hydroseeded material had rooting depths of only 2 to 3 inches.

The final monitoring was conducted in December 2008. At that time the project was performing great with no visual signs of erosion or storm water runoff of the site. Soil profiles also looked good with appropriate moisture and compost level deep into soil profile. At that time because of the poor germination of the hydroseed mix at the initial project installation the contractor removed a portion of the mulch and straw from a 50’ x 50’ section of the slopes and hand seeded this area with the original seed mix specified for this project. This was done to verify if the added mulch or straw thickness adversely affected the hydroseed germination. Further monitoring is recommended to more fully evaluate the success of the application of the *SRE System* to this slope.

6. Lotus Site

6.1 Summary of Existing Conditions

The “*Lotus Site*” is located at PM 24 -24.5 on Highway 49 in El Dorado County. The site consists of a generally northeast-facing cut slope excavated during widening of this section of the highway. The slope is located along the southwesterly side of the highway (*see Photo 6*). The slope is approximately 400 feet long, attains a maximum height of approximately 45 feet, with a maximum slope inclination of approximately 1.5 to 1 (horizontal to vertical). The original revegetation efforts, consisting of hydroseeding with a native species seed mix, subsequent to excavation of this slope have been deemed generally ineffective. The slope face experienced minimal plant germination, shallow rooting depths, indications of downslope soil erosion, and several localized areas of fairly shallow surficial slope slumping. There also was an accumulation of eroded soils at the toe of the slope along the edge of the roadway.

6.1.1 Summary of Geotechnical Conditions

Observations of the exposed geologic/soils conditions were made by the project geotechnical consultant for the *Lotus Site*. Geotechnical documentation regarding the existing cut slope had been requested but was not provided for review. Based on limited surficial observations and review of a geologic map of the area, the geotechnical consultant concluded that the slope appears to be underlain by weathered Cretaceous granitic rock.

Weathering of the granitic rock has resulted in a natural, relatively sandy soil that is developed on and gradational with the underlying granitic rock. This natural soil is commonly called decomposed or disintegrated granitics (“DG”) or grus. The depth of the natural soil horizon is likely variable across the cut slope. With depth, the soil grades into unweathered rock. As exposed in exploratory pits excavated into the slope-face, the granitic soils were fairly friable (“crumbly”) when disturbed resulting in a fine to coarse sand material and disruption of relict rock texture. Though not observed during our site visits, occasional unweathered granitic rock boulders may exist within the decomposed granitic soils (known as corestones). The granitic soil had a fairly uniform texture and few joints or fractures were observed in the relict rock texture. Adversely-oriented joints and fractures may negatively influence deep-seated and surficial stability.

The geotechnical consultant also observed the localized areas of surficial soil slumping. These areas generally consisted of loose, surficial granitic soils that were apparently saturated during precipitation events and moved downslope.

6.2 Initial Construction Concept – Lotus Site

The initial *SRE System* construction concept for the *Lotus Site* was to key loose soil amendments on the soil surface into underlying rock, improve soil conditions for sustainable plant growth and reduce storm water runoff.
The proposed strategy included:

- Reduction of overland surficial water flow
- Incorporation of organics in the upper 12 inches to enhance water infiltration, and to increase rooting depths.
- Deeper tillage over some portions of the slope to increase the potential for deeper rooting depths and enhance infiltration to sustain plants over dry periods
- Incorporation of organics into soil profile include screened compost, that adds nutrients, organic matter and increases water holding capacity; and shredded green waste material that provide long-term nutrient infiltration.

The recommended method to accomplish these goals was called "fracture bench step" by Dr. Claassen which included the proposed incorporation of compost into the slope-face soils and mulch onto the slope surface with additional planting of shrubs and trees.

6.2.1 Geotechnical Concerns Regarding Initial SRE Construction Concept

The geotechnical consultant understood that the intent of the *SRE Pilot Study* was to apply the UC Davis' *SRE System* to the slope. The intent of this action would be to help reduce soil erosion, improve soil infiltration, reduce storm water runoff and improve planting root depths. It was stressed to the geotechnical consultant by Caltrans' representative and Dr. Claassen that this was a test project and would not adhere to typical engineering solutions to solve the surficial slope stability and soil erosion concerns, but was to incorporate the *SRE Pilot Study* goal and objectives as much as site conditions allowed.

The primary geotechnical concerns related to the implementation of the initial construction concept at the *Lotus Site* generally included the following items related to slope stability:

- Relatively steep slope inclination, approximately 1.5 to 1 (horizontal to vertical) at the *Lotus Site*

- Placement of loosely compacted, organics-amended soils on a cut slope without typical compactive efforts

- Existing slumping of surficial soils and potential for future slumps

- Narrow roadway shoulder and nearby travel lane at base of slope

- Stability of existing surficial soils

The existing site conditions and geotechnical concerns required modifications to the initial construction concept. Based on field discussions and observations, the geotechnical consultant, Dr. Claassen and the landscape architect/contractor developed a modified construction plan that was adapted to the existing site conditions and still attempted to meet the *SRE Pilot Study* project objectives at the *Lotus Site as well as geotechnical objectives*. Where applicable, the geotechnical recommendations for each step of the field implementation sequence are summarized in Section 6.4.

6.3 Amended Soil Descriptions – Lotus Site

Following are the descriptions of the amended soil materials and seed mix used during *SRE Pilot Study* construction activities at this site. These terms as described below are used exclusively in subsequent sections for this *Lotus Site* and should not be considered applicable to the other *SRE Pilot Study* sites. As per the project-specific *Project SRE Report* specified mulch and compost was be placed and incorporated into the soil profile as directed. Incorporation of organic amendments such as yard waste compost provides easier rooting after incorporation and provides a blend of nutrients for a wide range of soil and plant growth conditions. Addition of woody mulch material applied to soil surface assists in erosion control, increased water infiltration into the soil substrate and provides a protective cover for plant establishment.

As per the *Project SRE Report* a typical blend of 50:50 yard waste compost screened to 10mm (3/8 inch minus) and woody shred mulch material was applied to the project surface then incorporated and mixed into the soil profiled to a depth of 10 inches to provide an available source of nutrients for plant establishment and an assessable soil substrate for easy deep root establishment.

> "Compost" at this site generally consisted of 1 inch minus garden humus "yard waste compost" supplied by Agromin
>
> "Mulch" used at this site generally consisted of "woody brush shredded material" supplied by Agromin.
>
> The "native seed mix" at this site generally consisted of native grasses and shrubs (See seed mix below)
>
> Container shrubs planted at this site included one gallon containers and liners (See plant list below)

<u>Plant legend</u>

	material	***Botanical/Common***	***Cont***
1.	CEA BUC	Ceanothus cuneatus/Buckbrush	Liner
2.	JUG WAL	Juglans californica 'Hindsii'/N California Black Walnut	Liner
3.	RHA COF	Rhamnus californica 'Tomentella'/Coffeeberry	Liner
4.	SAM MEX	Sambucus mexicana/Mexican Elderberry	Liner

<u>Hydroseed Legend</u>

	Species	***PLS WT/Acre***
1.	Elymus glaucus	5.97
2.	Nassella pulchra	5.97

3.	Bromus carinatus, El Dorado	4.03
4.	Leymuss triticoides	5.97
5.	Muhlenbergia rigens	4.03
	Total	25.97

6.4 SRE Field Implementation Sequence

The *Lotus Site* slope is relatively steep with a gradient of roughly 1.5 to 1 (horizontal to vertical). This slope is underlain by decomposed granitic soils that were easily subject to raveling upon disturbance. These factors influenced and limited the field implementation activities at the site. The steepness of the slope prohibited equipment from "walking" on the slope. Discussions between the project team members about the actual field conditions, geotechnical concerns, construction equipment limitations, and possible effective construction techniques resulted in modifications to the initial construction concept. Following is a summary of the actual field tasks that were performed at the *Lotus Site*.

6.4.1 Clearing and Grubbing

The *Lotus Site* was cleared of invasive weeds and grasses by hand pulling and excavation with hand tools. Some of the grasses were also mechanically trimmed down to the ground surface.

6.4.2 Amendment Distribution

To distribute the amendments, the surface of the *Lotus Site* slope area was initially covered with a one-inch thick blanket of these amendments. The amendments consisted of a 0.5-inch thickness of compost and a 0.5-inch thickness of mulch (as described in Section 6.3). Because of the steepness of the slope and the potential for adverse raveling of the sandy granitic soils the project team decided not to incorporate added soil amendments to the site surface soil profile as per the original *SRE Program* concept.

After the initial application of the mulch and compost to the slope surface the project team decided to test two additional incorporation techniques for specific localized areas. These additional techniques were added to test techniques that provided deep cracking of the soil profile and deeper incorporation of soil amendments into the soil profile needed to improve storm water infiltration and better plant rooting depths.

6.4.3 Additional Soil Profile Modifications

Two additional soil profile modification efforts were performed at the *Lotus Site*.

a. The first modification used a Caterpillar track excavator with a 3-foot wide bucket to excavate pits that disturbed the existing in-place soils and incorporate additional amendments. The pits were approximately 6 feet wide and 4 feet deep. The excavated soil was amended with 25 percent compost and mulch mix to 75 percent native soil and replaced back into the hole and the slope surface was restored and recompacted in place using the excavator bucket to tamp the soil back in place. These pits were spaced approximately 15 feet apart across the slope face in a random pattern as directed by the Dr. Claassen and the project geological consultant.

b. The second modification used a Caterpillar track excavator with an impact breaker attachment to disturb the existing in-place soils by fracturing localized areas on the slope. The resultant depressions were approximately 1 foot wide and 2 to 3 feet deep. Disturbance of the granitic soils adjacent to the impact points occurred and extended approximately 3 feet laterally in all directions from the impact depressions. Amendments were incorporated into the disturbed areas and the slope surface was restored and recompacted in place to an estimated rate of 85% relative compaction. These impact holes were spaced approximately 5 feet apart across the slope face in a random pattern of clusters. This technique is shown on *Photo 7*.

All of these additional soil profile modification areas were used to install containerized plants used to test methods for improving water and nutrient infiltration and increased plant rooting depths. During these *Additional Soil Profile Modification* efforts, the geotechnical consultant recommended limiting the spacing of these pits such that a continuous interface between the disturbed soils and underlying undisturbed soils was not developed and this interface was not parallel to the existing slope face. Intervening areas of generally undisturbed slope-face soils were desired by the geotechnical consultant. Therefore, it was agreed by the team to limit larger 4'by 6' pits to a minimum random spacing of 15 feet. It was also suggested by the team that the impact holes be a minimum of 5 feet apart in randomly-spaced clusters.

6.4.4 Stabilization of Surficial Soil Slumps

Several localized areas of fairly shallow surficial soil slumps were observed on the slope face at the *Lotus Site* (*see Photo 8*). Exploratory pits were excavated into these slumps so the geotechnical consultant could observe the failure surfaces. The interface between undisturbed soils and slumped soils was observed. No out-of-slope feature inherent in the granitic rock, such as joints, was observed. Previous excavation activities at the site appeared to have left a veneer of loose soils on the cut slope. Apparently these surficial soils and the overlying hydroseed coating had become saturated during precipitation events and mobilized downslope. The surficial soil slumps generally extended less than 6 inches in depth.

To stabilize these slump areas and restore the slope face configuration, a repair scheme was discussed in the field by the geotechnical consultant and landscape architect/contractor. The stabilization method consisted of the excavation of three roughly horizontal benches across the localized slumped areas. The benches were excavated to a depth that disrupted the failure surface and extended into the underlying undisturbed soils. The excavated soils were then replaced, moisture-conditioned, placed in lifts, and recompacted to a minimum level acceptable to the geotechnical consultant (using a soil probe). These benches were roughly 20 feet long and 3 feet deep.

The geotechnical consultant determined that the spacing of these benches be such that a continuous interface between the disturbed soils and underlying undisturbed soils was not developed and this interface was not parallel to the existing slope face. Large undisturbed areas of slope-face soils remained between the benches to maintain slope stability.

6.4.5 Landscape Installation

The final field activities at the *Lotus Site* included landscaping of the slope face. Landscaping included the application of hydroseeding with the native seed mix described in Section 6.3. Subsequently, the slope was dressed with a straw blanket and an approximately 1-inch blanket of mixed mulch and compost. This blanket was applied to protect the hydroseed mix and to help retain soil moisture during plant establishment. Jute netting was installed across the entire slope to assist in soil retention and erosion control. Container plants (as described in Section 6.3) were also planted in random groups at test pits and impact hole locations as directed by Dr. Claassen.

6.5 Geotechnical Comments

The geotechnical consultant understood that the intent of the *SRE Pilot Study* was to apply the UC Davis' *SRE System* to the slope. The intent of this action was to demonstrate that the *SRE System* may help reduce soil erosion, improve soil infiltration, reduce storm water runoff and improve planting root depths as well as maintaining the geotechnical stability of the project. It was stressed to the geotechnical consultant by the Caltrans' representative and Dr. Claassen that this was a test project and would not adhere to typical engineering solutions to solve the surficial slope stability and soil erosion concerns, but was to incorporate the *SRE Pilot Study* goal and objectives as much as site conditions allowed.

Observations of the exposed geologic/soils conditions were made by the project geotechnical consultant for the *Lotus Site*. Geotechnical documentation regarding the existing cut slope had been requested but was not available at that time. The *Lotus Site* slope is relatively steep with an approximate inclination of 1.5 to 1 (horizontal to vertical). The steep slope is more prone to downslope movement of surficial soils by the activities of surface water and gravity. Slope flattening was suggested by the geotechnical consultant but was not considered an acceptable component for success of the *SRE Pilot Study* project.

The *Lotus Site* slope is underlain by natural, relatively sandy soil that is developed on and gradational with the underlying granitic rock. The granitic soil had a fairly uniform texture and few joints or fractures were observed in the relict rock texture. Adversely-oriented joints and fractures that may negatively influence deep-seated and surficial stability were not observed. The granitic soils were fairly friable ("crumbly") when disturbed resulting in a fine to coarse sand material that "raveled".

During the *Soil Profile Modifications* efforts (as described in Section 6.4.3), pits and fractured areas disturbed the soils on the slope. The geotechnical consultant recommended that the spacing of these pits were such that a continuous interface between the disturbed soils and underlying undisturbed soils was not developed and this interface was not parallel to the existing slope face. Undisturbed areas of slope-face soils exist between the pits and fractured areas.

The *SRE Pilot Study* activities disturbed areas of the slope-face soils. An advantage of the disturbed soils is the potential for more avenues for water to reach greater rooting depths. A disadvantage is the introduction of water into areas of poorly-compacted soils.

6.6 Lotus Site Construction Summary

The *Lotus Site* was the second demonstration slope constructed as part of the *SRE Pilot Study*. This slope was relatively steep with a gradient of 1.5 to 1 (horizontal to vertical). Several localized areas of surficial soil failures were observed on the slope face. Minimal plant germination had occurred from previous hydroseeding efforts.

During initial efforts, the project team performed field evaluation of the different techniques suggested to incorporate the soil amendments and attain the *SRE Pilot Study* project goals. The steepness of the slope prohibited equipment from "walking" directly on the slope face. Soil incorporation was performed by equipment based either at the top or the base of the slope and was also performed by manual labor.

A general consensus of the project team was reached regarding a modified construction plan to attain project goals. Subsequently, the landscape architect/contractor proceeded under direction of the project team to install the project using a production-type construction operation method.

The overall construction process once developed was easily installed using typical road construction equipment. The various construction process as detailed in section 6.4 provided an efficient production sequence to implement the proposed *SRE System* that met the projects goals and objectives. This production sequence was cost effective and could be done as part of initial roadway projects or retrofit projects.

This overall production sequence was relatively cost effective and could be easily installed as part of the initial roadway project or as a separate retrofit project. This process typically would increase standard Erosion Control Type "D" process labor approximately an additional 3-4 days per acre and adding an additional cost of 70 cents per square foot to the original typical construction operation cost.

6.7 Post-Installation Site Observation

The *Lotus Site* was observed on three subsequent occasions by the project landscape architect/contractor to observe project performance. Site visits occurred two months, four months and 8 months after substantial completion of the construction activities. A photo of the slope four months after completion is included as *Photo 9*.

During the site visit two months after the completion of the construction, the site was experiencing heavy rainfall during a several-day precipitation event. There were no apparent indications of storm water runoff or soil erosion on the slope face. The slope had been entirely covered with jute net and observation of previous surficial soil slumps was very limited, but no indications of downslope movement were apparent. The plant material planted from containers were all living and in apparently good condition. Heavy rains precluded more detailed observations at that time, however, the landscape architect/contractor and geotechnical consultant concluded that the project was performing better than anticipated, with the project showing minimal to no soil erosion and surficial rilling. The project site also had no signs of soil surface sluffing or slipping as previously feared.

At the four-month site review the *Lotus Site* was observed to be performing as intended and had no indications of storm water runoff or soil erosion. Observations of the previous slope failure areas indicated no apparent signs of movement. The plant material from containers was generally thriving with only a minimal mortality rate. Two plants were excavated and were evaluated for their root growth. Both plants showed signs of deepened root growth because of the amended soils. However, the landscape architect noted that the germination of the hydroseeded mix was less than expected. Hydroseeding had been done prior to the cold winter weather and snow. The inclement weather was the reason for the slow germination, as suggested by seed manufacturer. This project should be rehydroseeded the following year so as to attain a proper evaluation of the hydroseeding techniques.

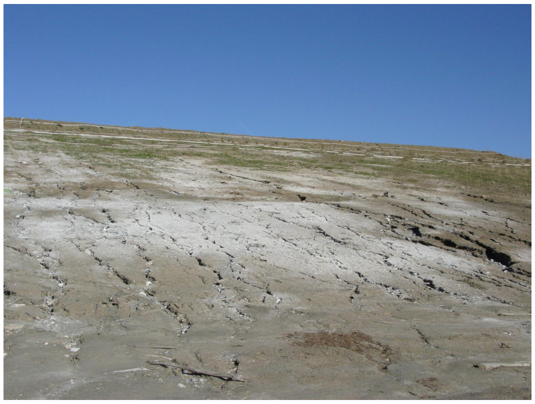
The final monitoring was conducted in December 2008. At that time the project was performing great with no visual signs of erosion or storm water runoff of the site. Soil profiles at test pits also looked good with appropriate moisture and compost level deep into soil profile. At that time because of the poor germination of the hydroseed mix at the initial installation the contractor overseeded a portion of the slope by hand with the original seed mix specified for this project. Further monitoring is recommended to more fully evaluate the success of the application of the *SRE System* to this slope.

7. Templin Site – Two Test Site Areas

7.1 Summary of Existing Conditions

The "*Templin Site*" is located at PM 65.4 on the west side of the I-5 freeway, south of the Templin Highway exit, in northern Los Angeles County. The *Templin Site* consists of two areas of recently graded, sloping terrain:

> "*Templin Slope Test Site*" - The southern, steeper "slope" area consists of a cut slope with a gradient of roughly 2 to 1 (horizontal to vertical) (*see Photo 10*). The area treated with the *SRE System* as part of this *SRE Pilot Study* was approximately 320 feet by 80 feet.



"Templin Flats Test Site" – The northern "flats" area consists of a graded slope with a relatively gradual gradient of roughly 5 to 1 (horizontal to vertical) (*see Photo 11*). The area treated with the *SRE System* as part of this *SRE Pilot Study* was approximately 120 feet by 120 feet.

Both of the *Templin Site* areas were recently graded as part of the mitigation of a large landslide mass that had impacted the travel lanes of the I-5 freeway. Surface and subsurface drainage provisions to remove groundwater from the landslide mass were also installed as part of the landslide mitigation.

Vegetation efforts subsequent to grading of the *Templin Site* areas have been deemed generally ineffective. The hydroseeding of the surficial soils in both areas experienced minimal to no plant germination. Additionally, container planting on the *Templin Slope* were not performing well, even with irrigation efforts. At both *Templin Site* areas, there were obvious indications of downslope soil erosion and gullying due to concentrated surface water flows.

7.1.1 Summary of Geotechnical Conditions

The previous grading at the *Templin Site* was performed for the mitigation of a large landslide that had impacted the travel lanes of the I-5 freeway. Geotechnical information regarding the landslide mitigation is included in the following reports obtained from Caltrans:

> *"Geotechnical Design Report for the Mitigation of an Emergent Landslide Affecting Southbound and Northbound Interstate 5 at Postmile 65.4 to 65.7, 07-4K9403, Templin Highway"* , dated April 21 and 23, 2005 (two dates on two "final draft" text versions), by Caltrans, Roadway Geotechnical Design South-1
>
> *"Preliminary Geotechnical Recommendations for Pavement Rehabilitation on I-5 South of Templin Highway"*, Draft memorandum dated February 1, 2008, by Caltrans, Office of Geotechnical Design – South 1

A cursory review of these reports for relevant soils/geologic information regarding the soils/geologic conditions at the *Templin Site* was performed by the *SRE Pilot Study* geotechnical consultant. In addition, the geotechnical consultant briefly spoke with Mr. Jeff Kermode, an engineering geologist with Caltrans regarding the landslide investigation and geotechnical conditions at the *Templin Site*. Preliminary surficial observations of the exposed soils/geologic conditions were made during site visits.

Based on limited observations and the review of the Caltrans' geologic information, the southern *Templin Slope* area appears to be underlain by the Miocene sedimentary bedrock unit known as "Paradise Shale Member of the Peace Valley Formation of the Ridge Basin Group". The Paradise Shale primarily consists of claystone/siltstone with minor interbeds of sandstone. At the southern *Templin Slope* area, the easterly-facing slope exposes bedding of the Paradise Shale that dips moderately to steeply out of slope. Out-of-slope bedding is typically considered a negative factor that contributes to deep-seated and surficial instability of a slope. A "pop-out" type of failure was observed on the slope face to the north of the *Templin Slope* demonstration plot. It is likely that the stability of this slope was evaluated by Caltrans during landslide mitigation grading, however, an as-built geotechnical report was not available for review by the geotechnical consultant.

The northern *Templin Flats* area is less steep topographically and appears to be underlain by landslide deposits. As observed by the geotechnical consultant in exploratory trenches excavated in this area, the landslide deposits generally consisted of fractured and sheared Paradise Shale. Groundwater films were apparent on some of the fracture surfaces within the landslide deposits exposed in the trenches. The representative soil sample collected at the *Templin Flats* area was tested in general accordance with laboratory standard ASTM 4829. The test yielded an expansion index of 80, which indicates a medium expansion potential. Indications of highly expansive clayey soils were also observed at the site.

7.2 Initial Construction Concept – Templin Site

The initial *SRE System* construction concept for the *Templin Site* areas was to improve the growing conditions for plants to improve soil conditions for sustainable plant growth and reduce storm water runoff.

The proposed strategy included:

- Reduction of overland surficial water flow
- Incorporation of organics in the upper 12 inches to enhance water infiltration, and to increase rooting depths-(clarify later that didn't do this and why
- Deeper tillage over some portions of the slope areas to increase the potential for deeper rooting depths and to enhance infiltration to sustain plants over dry periods
- Incorporation of organics amendments into soil profile that include screened compost, that adds nutrients, organic matter and increases water holding capacity; and shredded green waste material that provides long-term nutrient infiltration.

The recommended methods to accomplish these goals were called "hydraulic hammer hole clusters", "pocket/step excavations', and "diamond ripping pattern" by Dr. Claassen and included the proposed incorporation of compost into the surficial soils, mulch on the slope surfaces and container shrubs at a spacing of greater than 7 feet.

7.2.1 Geotechnical Concerns Regarding Initial SRE Construction Concept

The geotechnical consultant understood that the intent of the *SRE Pilot Study* was to apply the UC Davis' *SRE System* to the slope. The intent of this action would be to help reduce storm water erosion and revegetate the slope with native species. It was stressed to the geotechnical consultant and landscape architect/ contractor by the Caltrans project manager and Dr. Claassen that this was a research project and would not incorporate typical engineering solutions to solve the surficial slope stability and soil erosion concerns, but was to incorporate the *SRE Pilot Study* goals and objective as much as site conditions allowed..

The primary geotechnical concerns related to the implementation of the initial construction concept at the *Templin Site* generally included the following items related to slope stability:

- Disturbance of areas associated with an engineered stabilization of a large landslide mass impacting travel lanes of the I-5 freeway.
- Out-of-slope geologic bedding in the *Templin Slope* area and potential for negative impact by proposed construction schemes.

- Relatively steep slope inclination of the *Templin Slope.*

- Placement of loosely compacted, organics-amended soils on a cut slope without typical compactive efforts (*Templin Slope*).

- Introduction of irrigation waters into a large landslide mass

The existing site conditions and geotechnical concerns required some modifications to the initial construction concept. Based on field discussions, the project team developed a modified construction plan that was adapted to the existing site conditions and still attempted to meet the *SRE Pilot Study* project objectives at the Templin Highway Site

7.3 Amended Soil Descriptions – Templin Site

Following are the descriptions of the amended soil materials and seed mix used during *SRE Pilot Study* construction activities at this site. These terms as described below are used exclusively in subsequent sections for this *Templin Site* and should not be considered applicable to the other *SRE Pilot Study* sites. As per the project-specific *Project SRE Report* specified mulch and compost was be placed and incorporated into the soil profile as directed. Incorporation of organic amendments such as yard waste compost provides easier rooting after incorporation and provides a blend of nutrients for a wide range of soil and plant growth conditions. Addition of woody mulch material applied to soil surface assists in erosion control, increased water infiltration into the soil substrate and provides a protective cover for plant establishment.

As per the *Project SRE Report* a typical blend of 50:50 yard waste compost (screened to 10mm (3/8 inch minus) and woody shred mulch material was applied to the project surface then incorporated and mixed into the soil profiled to a depth of 10 inches to provide an available source of nutrients for plant establishment and an assessable soil substrate for easy deep root establishment.

"Compost" at this site generally consisted of 1 inch minus garden humus "yard waste compost" supplied by Agromin

"Mulch" used at this site generally consisted of "woody brush shredded material" supplied by Agromin.

The "native seed mix" at this site generally consisted of native grasses and shrubs (See seed mix below)

Container shrubs planted at this site included one gallon containers and liners. (See plant legend below)

Templin Highway Site (Templin Slope Area)

Plant legend

		Botanical/Common	*Cont*
1.	BAC PIL	Baccharis pilularis/Dwarf Coyote Brush	1 gal
2.	ERI FAS	Enogonum fasciculatum/Common Buckwheat	Liner
3.	LEY CON	Leymus condensatus/Giant Wild Rye	1 gal
4.	NAS PUL	Nassella pullchra/Purple Needle Grass	Liner
5.	SAL PU3	Salvia leucophylla/San Luis Purple Sage	1 gal
6.	SAL MEL	Salvia mellifera/Black Sage	Liner

Seed Legend

	Species	*PLS/WT/Acre*
1.	Artemisia tridentate	.50
2.	Leymus condensatus	1.00
3.	Nassella pulchra, deawned	4.00
4.	Nassella lepida, deawned	2.00
5.	Poa secunda	1.00
6.	Eriogonum fasciculatum	1.00
7.	Lotus scoparius	3.00
8.	Lotus purshianus	2.00
9.	Malacothamnus fremonti	.20
10.	Atriplex lentiformis	1.00
11.	Artemisia californica	.50

Templin Highway Site (Templin Flat Area)

Plant legend

	Shrubs	*Botanical/Common*	*Cont*
1.	BAC PIL	Baccharis pilularis/Dwarf Coyote Brush	1 gal
2.	ERI FAS	Enogonum fasciculatum/Common Buckwheat	Liner
3.	LEY CON	Leymus condensatus/Giant Wild Rye	1 gal
4.	NAS PUL	Nassella pullchra/Purple Needle Grass	Liner
5.	SAL PU3	Salvia leucophylla/San Luis Purple Sage	1 gal
6.	SAL MEL	Salvia mellifera/Black Sage	Liner

Seed Legend

	Species	*PLS/WT/Acre*
1.	Artemisia tridentate	.50
2.	Leymus condensatus	1.00
3.	Nassella pulchra, deawned	4.00
4.	Nassella lepida, deawned	2.00
5.	Poa secunda	1.00
6.	Eriogonum fasciculatum	1.00
7.	Lotus scoparius	3.00
8.	Lotus purshianus	2.00
9.	Malacothamnus fremonti	.20
10.	Baccharis pilularis	.10
11.	Atriplex lentiformis	1.00

12. Artemisia californica .50

7.4 SRE Field Implementation Sequence

The *Templin Slope Site* is steeper than the *Templin Flats Site* area and consists of different soil profiles. This *Templin Slope Site* is underlain by hard shale consisting of siltstone/claystone with minor interbeds of sandstone. The *Templin Flats Site* area is apparently underlain by landslide deposits derived from the shale. The following is a summary of the actual field tasks that were performed at the two *Templin Site* areas.

Discussions between the project team members about the actual field conditions, geotechnical concerns, construction equipment limitations, and possible effective construction techniques resulted in modifications to the initial construction concept. Following is a summary of the actual field tasks that were performed at both the *Templin Slope Site* and the *Templin Flat Site*.

7.4.1 Clearing and Grubbing

Both *Templin Site* areas were generally free of vegetative cover. The previously-planted container plants on the *Templin Slope* were dug up and containerized for future planting efforts. Also the temporary irrigation pipes were removed from both areas and existing systems capped off. Additional weeds and grasses were removed.

7.4.2 Amendment Distribution

Because the *Templin Slope Site* and *Templin Flats Site* were substantially different, two different types of soil amendment incorporation techniques were implemented. The following is a summary of the amendment incorporation techniques for each site:

Templin Slope Site

One inch of compost and one inch of mulch were placed onto the entire site surface, for a total of two inches of amendments (per the *SRE System* report) and were amended into the soil profile using various techniques.

Since this *Templin Slope Site* consisted primarily of shale that could not be disturbed much without destabilizing the slope, the soil amendments were only incorporated into the soil profile to an approximate depth of 4 to 6 inches below the ground surface. This incorporation was accomplished by placing the compost and mulch over the entire site and the using the excavator bucket to loosen and scrape a few inches of the shale and mix it with the site amendments to create a surficial, amended soil. It was noted by the Dr. Claassen and the project geologist that if infiltration into the geological layers underneath this shallow blanket layer of porous substrate/organic materials is restricted and becomes saturated, the surface blanket layer can be expected to liquefy and run down the slope. Therefore, in other areas additional techniques were used to establish deeper amendment incorporation into the soil profile and to key these amended areas into the underlying geological materials. Conversely, if the porosity and plant growth of the surface blanket treatment remains high, percolation will be high enough to avoid saturation and positive pore pressure, providing a think mulch layer for raindrop protection.

Templin Flats Site

One-and-one-half inches of compost and one-and-one-half inches of mulch were placed onto the entire site surface, for a total of three inches of amendments (per the *SRE System* report) and were amended into the soil profile using various techniques.

A D-6 Track Dozer with 36-inch ripping teeth was used to horizontally rip and incorporate soil amendments from 24 to 36 inches deep into the soil profile for the entire project area. This method work well at breaking up the soil, but did not get enough amendment blended throughout the soil profile. Therefore, the site was also cross ripped using a skip loader with 12 inch ripping teeth that mixed and incorporated the amendments throughout the soil profile to the satisfaction of the project team. Subsequently, the skip loader conducted final passes over the site to flatten the larger rows created by the skip loader's initial passes and finished the soil surface with small 4-inch furrows that were horizontal to the bottom of the slope (*see photo 12*). These 4-inch furrows acted as diversions to eliminate potential negative effects of downslope surficial water runoff.

After the initial incorporation of the mulch and compost to the slope the project team decided to test two additional amendment incorporation techniques for specific localized areas. These additional techniques were added to test techniques that provided deep cracking of the soil profile and deeper incorporation of soil amendments into the soil profile needed to improve storm water infiltration and better plant rooting depths.

7.4.3 Additional Soil Profile Modifications

Two additional soil profile modification efforts were performed at both *Templin Sites-*.

a. The first additional modification technique used a track excavator with a 3-foot wide bucket to excavate pits that disturbed the existing in-place soils and incorporate additional amendments. These pits were approximately 6 feet wide and 4 feet deep. The excavated soil was amended with compost and mulch, replaced back into the hole and the slope surface was restored and recompacted using the excavator bucket to tamp the soil back in place. These pits were spaced approximately 15 to 20 feet apart in a random pattern across the slope face.

b. The second modification technique used the same track excavator with an impact breaker attachment to create impact holes in the existing in-place soils by fracturing localized areas on the slope. The resultant impact holes were approximately 1 foot wide and 2.5 to 3 feet deep. Fracturing of the soils occurred adjacent to the impact points and extended approximately 3 feet laterally in all directions from the initial impact holes.

   During these *Additional Soil Profile Modification* efforts the geotechnical consultant recommended limiting the spacing of these pits such that a continuous interface between the disturbed soils and underlying undisturbed soils was not developed and this interface was not parallel to the existing slope face. Intervening areas of generally undisturbed slope-face soils were desired by the geotechnical consultant. Therefore, it was agreed by the team to limit larger 4' by 6' pits to a minimum spacing of 15 feet and to be randomly spaced. It was also suggested by the team for the impact holes to be a minimum of 5 feet apart in randomly spaced clusters so as not to destabilize the existing slopes.

Both of these soil profile modification methods were used to install containerized plants and were anticipated to provide improved nutrient and moisture incorporation into the soil profile and plant rooting depths.

7.4.4 Landscape Installation

The final field activities at the *Templin Site* included landscaping of the *Templin Slope* and *Templin Flats* areas. Landscaping included the application of hydroseeding with the native seed mix described in Section 7.3. Subsequently, the two areas were dressed with an approximately 2-inch blanket of mulch. This blanket was applied to protect the hydroseed mix and to help retain soil moisture during plant establishment. Container plants (as described in Section 7.3) were planted in random groups located in test pits and impact holes and backed filled with amended soils as outlined in the *SRE Report.*

7.5 Geotechnical Comments

The geotechnical consultant understood that the intent of the *SRE Pilot Study* was to apply the UC Davis' *SRE System* to the slope. The intent of this action would be to help reduce soil erosion and revegetate the slope with native species. It was stressed to the geotechnical consultant and landscape architect/contractor by the Caltrans project manager and Dr. Claassen that this was a research project and would not incorporate typical engineering solutions to solve the surficial slope stability and soil erosion concerns, but was to incorporate the *SRE Pilot Study* goals and objective as much as site conditions allowed..

The previous grading at the *Templin Site* was for the mitigation of a large landslide that had impacted the travel lanes of the I-5 freeway. Two areas were used for the *SRE Pilot Study*: the southern *Templin Slope* area and the northern *Templin Flats* area.

The southern *Templin Slope* area appears to be underlain by the Miocene sedimentary bedrock unit known as "Paradise Shale Member of the Peace Valley Formation of the Ridge Basin Group". The Paradise Shale primarily consists of claystone/siltstone with minor interbeds of sandstone. At the southern *Templin Slope* area, the easterly-facing slope exposes bedding of the Paradise Shale that dips moderately to steeply out of slope. Out-of-slope bedding is typically considered a negative factor that contributes to deep-seated and surficial instability of a slope.

The northern *Templin Flats* area is less steep topographically and appears to be underlain by landslide deposits. The landslide deposits generally consisted of fractured and sheared Paradise Shale. Groundwater films were apparent on some of the fracture surfaces within the landslide deposits exposed in the trenches.

On the *Templin Slope* area, pits and fractured areas disturbed the soils on the slope. The geotechnical consultant recommended that the spacing of these pits and fractured areas be such that a continuous interface between the disturbed soils and underlying undisturbed soils was not developed and this interface was not parallel to the existing slope face. Between the pits and fractured areas, light raking by the excavator bucket incorporated amendments into surficial soils to a depth of approximately 4 to 6 inches. The primary concern of the geotechnical consultant was the potential introduction of additional water into the recently stabilized landslide mass. The *Templin Slope* area also exposes out-of-slope bedding that may be more prone to failure, however, no structures currently exist that would be negatively impacted if a slope failure occurred.

On the *Templin Flats* area, the primary concern of the geotechnical consultant was the potential introduction of additional water into the recently stabilized landslide mass. Due to the relatively shallow slope, the geotechnical consultant did not have other site-specific concerns regarding the *Soil Profile Modification* activities in this *Templin Flats* area.

General surface mixing and blending of amendments was performed and tamping of the organics-amended soils into the pits on the *Templin Slope* area. However, due to the steepness of the slope, track-walking to achieve some recompaction was not feasible. Typically, fill soils are compacted to a minimum relative compaction of 90 percent, based on laboratory standard ASTM D1557. Therefore, the organics-amended fill soils were placed and compacted to an estimated 80 to 85 percent level less than the typical 90 percent relative compaction.

Some other site factors were considered by the geotechnical consultant include that the two *Templin Site* demonstration plots are considered remote and are not directly adjacent to roadways and structures. Regular vehicular and pedestrian traffic is not anticipated at or near the two treated *Templin Site* areas. Also infiltration of water into the landslide mass is not desired so the geotechnical consultant discouraged a more permanent irrigation system for the two *Templin Site* demonstration areas.

7.6 Templin Highway Site Construction Summary

The two areas of the *Templin Site* were the last demonstration plots constructed as part of the *SRE Pilot Study*. The *Templin Site* includes the 2 to 1 *Templin Slope* and the 5 to 1 *Templin Flats* areas. Minimal plant germination had occurred from previous hydroseeding efforts in both of these graded areas.

During initial efforts, the project team discussed the different techniques that had been used on the previous *SRE Pilot Study* sites to incorporate the soil amendments and attain the *SRE Pilot Study* project goals. Soil amendment incorporation was performed by equipment based at the toe of the *Templin Slope* and was also performed by manual labor in this area. The *Templin Flats* area was easily accessible by construction equipment and deeper amending of the soil profile was possible.

A general consensus by the project team was reached regarding a modified construction plan to attain project goals. Subsequently, the landscape architect/contractor proceeded under direction of the project team to install the project using a production type construction operation method.

The overall construction process once developed was easily installed using typical road construction equipment. The various construction process as detailed in section 7.4 provided an efficient production sequence to implement the proposed *SRE System* that met the projects goals and objectives. This production sequence was cost effective and could be done as part of initial roadway projects or retrofit projects.

This overall production sequence was relatively cost effective and could be easily installed as part of the initial roadway project or as a separate retrofit project. This process typically would increase standard Erosion Control Type “D” process labor approximately an additional 3-4 days per acre and adding an additional cost of 70 to 75 cents per square foot to the original typical construction operation cost.

7.7 Post-Installation Site Observation

The *Templin Site* was observed on three subsequent occasions by the project landscape architect/contractor to observe project performance. Site visits occurred two months, four months and six months after substantial completion of the construction activities. A photo of the slope four months after completion is included as *Photo 13*.

During the site visits, there were no apparent indications of storm water runoff or soil erosion on the *Templin Slope* or *Templin Flats* areas. The plant material planted from containers was in good condition, however, the germination of the hydroseeded mix was less than expected. This was likely because it was hydroseeded late in the year and most of the seed went dormant in the summer period. The landscape architect/contractor and geotechnical consultant concluded that the project was performing better than anticipated, with the project showing minimal to no soil erosion and storm water runoff. The project site also had no signs of soil surface sluffing or slipping as previously feared. Container plant material was doing great and had plenty of new growth. Several plants were excavated and observed that the plant root structure had extended root structures deep into the soil profile. Also soil profiles were excavated and showed signs of moisture retention as compared to non treated soils adjacent project test site which no signs of moisture retention. Further monitoring is recommended to more fully evaluate the success of the application of the *SRE System* for the two *Templin Site* areas.

8. Construction Costs – SRE Pilot Study

The *SRE Pilot Study* included three demonstration test sites with different site conditions. Considering this was a pilot project, the development of new techniques of incorporating amendments into the soil profile using varying types of equipment was a significant challenge. However, the project team did find techniques to implement the *SRE System* concept in a production-type manner. The following is a list of construction material costs, equipment rental rates and square-foot rates for estimating future project costs. These costs are generally conservative and are limited to typical labor and materials costs with standard of industry mark-ups for overhead and profit. These costs do not include contractor mobilization, travel time or other contractor fees that may depend on project size and location. These costs only reflect labor and material costs in a production rate, as evaluated during this pilot project. Larger projects will likely increase production rates and reduce construction costs.

(Method #1 Typical Site with 2:1 Slopes or Less)

Materials

Item	**Unit**	**Unit Cost**	**Cost Per Acre**
2” Thick Mulch	SF	$0.13	$5,662
2 “ Thick Compost	SF	$0.13	$5,662
Jute Net	SF	$.35 (Optional)	
8” Straw Wattles	LF	$.75	$2,380
Rock Channel	SF	$5.00 (Optional)	
Hydroseeding	SF	$0.09	$3,920
Plant Material	EA	$5.00 (800)	$4,000
		Total	**$21,624**

Equipment

Item	**Weekly/ Rate with Fuel**	**Cost Per Acre**
D-6 Dozer	$1,500 (Amendment Incorporation soil profile)	$1,200
4WD Skip Loader	$1,000 (Amendment Incorporation soil profile)	$750
Excavator	$1,700 (Amendment Incorporation shallow surface & 4’x6’ Holes)	$1,400
Impact Attachment	$1,400 (Impact Holes)	$1,000
Water Truck	$1,200	$500
	Total	**$4,850**

Labor:
5 man crew @ $65/hr for (5 days) = $13,000

Method #1
(This may be considered typical for a site that has stable slope conditions with 2:1 slope steepness or less steep slopes.)

The following estimate value is for performing ripping of surficial soils, amendment incorporation, applying impact holes for planting pits, adding 4’x6’ excavation pits, hydroseeding, top dressing slopes with 2 inches of mulch/compost and 8 inch straw wattles at 15 feet on center.

Price per Acre = $39474 or $0.91 SF

(Meth #2 Typical Slopes over 2:1 Slope)

Materials

Item	**Unit**	**Unit Cost**	**Cost Per Acre**
1” Thick Mulch	SF	$0.13	$2,831
1 “ Thick Compost	SF	$0.13	$2,831
Jute Net	SF	$.35 (Optional)	
8” Straw Wattles	LF	$.75	$2,380
Rock Channel	SF	$5.00 (Optional)	
Hydroseeding	SF	$0.09	$3,920
Plant Material	EA	$5.00 (1200)	$6,000
		Total	**$17,962**

Equipment

Item	**Weekly/ Rate with Fuel**	**Cost Per Acre**
4WD Skip Loader	$1,000 (Amendment Incorporation soil profile)	$750

Excavator	$1,700	(Amendment Incorporation shallow surface & 4'x6' Holes)	$1,400
Impact Attachment	$1,400	(Impact Holes)	$1,000
Water Truck	$1,200		$500
		Total	**$3,650**

Labor:
5 man crew @ $65/hr for (6 days) = $15,600

Method #2
This method is for a site where existing soils and site conditions limit incorporating amendments deep into soil profile. Only limited shallow surface soil incorporation of amendment 2" to 6" inches can be completed with additional deeper soil incorporation limited to selected or local areas such as planter pits and impact holes used to incorporate deeper soil amendments to improve plant rooting depths.

The following estimated value is for performing minor surface soil amendments, additional large planting pits, impact holes for plant material, hydroseeding, plant material from 1 gallon containers and liners, top dressing areas with 2 inches of mulch/compost and 8 inch straw wattles added at 15 feet on center for additional erosion control.

Price per Acre = $37,212 or $0.86 SF

9. Project Summary – SRE Pilot Study

The overall *SRE Project Concept* and construction for all the sites went well. The project team worked well together in overcoming site issues and developed several construction and erosion control techniques that met the project goals and objectives. Each of the constructed test sites were fundamentally different yet proved to significantly reduce storm water runoff and erosion. The sites were also observed to improve soil nutrients and moisture retention at soil profile and showed signs of increased plant rooting depths while maintaining the structural stability of the slopes.

While doing this project it was important to design and construct each of these sites under the direction of the project team which included the Caltrans representative, Dr. Claassen from UC Davis, project landscape architect, contractor and project geologist who all worked together to evaluate existing site conditions to determine and modify the SRE Program so the overall project goals and objectives were met.

In developing the *SRE Strategy* it is important to understand that pedologic processes generally take hundreds and thousands of years to develop the natural soil horizons that mantle natural ground surfaces. Gradational zones typically develop within the soil horizon, extending from the ground surface to the underlying unweathered rock. It is difficult to mimic natural soil development. The *SRE Strategy* employed in this *SRE Pilot Study* attempts to use amended soils to partially mimic natural soil development, promote revegetation of disturbed areas, increase water infiltration and subsequently control soil erosion and storm water.

In developing this project and the installation techniques we found that this program could be easily installed per the SRE Concept using typical roadway construction equipment. This program can be easily incorporated as part of a new roadway project using existing on-site equipment and adding only a few extra days to the construction timeline and at a reasonable cost as compared to the typical erosion control type “D”. This system greatly reduces erosion and storm water runoff on these sites at an average cost of about 0.70 cents/ SF. more that erosion control type “D”. However if developed as part of a new roadway project using existing on site equipment cost could be even lower.

However, the most important part of the project was reviewing the sites after four months of initial construction and seeing the benefits of this project on the existing sites. It was apparent that each site had significantly reduced storm water runoff and erosion and still maintained the stability of the slopes. The project activities also improved the soil make-up, moisture holding capacity and showed signs of improved the plant rooting depths.

In reflecting on the success of these sites, the potential for incorporating this program concept on future Caltrans projects is apparent and can be very successful. This system greatly improves soil infiltration and reduces erosion control and storm water runoff and with additional development of the project has the potential to be viable program However, these concepts still need refinement and need to further improve installation techniques and modifications of equipment to improve amendment incorporation techniques and increase product installation. Also processes need to be developed for evaluating the differences in project types, soils and slope stabilization and planting techniques.

10. Suggestions for Future SRE Project Implementation

The following is an outline of suggested future implementation procedures and construction incorporation techniques created and developed from the observations and lessons learned during the development of this *SRE Test Program.* This program proved to be quite effective in reducing storm water runoff and for plant material establishment and can be cost effectively installed using typical roadway equipment on new projects or installed as a retrofit project on existing sites.

10.1 Historical Review

A historic review of the project site needs to be completed prior to the development of design guidelines. This historic review shall include reviewing topographic maps, grading plans, soil reports, geological maps, surveys and any testing that have been completed in the past. It should also include review of past projects or projects located adjacent the purposed project. This information can assist in the development of the site specific SRE Project Concept and address any concerns for slope stability and project safety.

10.2 Site Analysis

Site analysis needs to be done for existing site conditions. This analysis should include visual review and necessary testing to include existing slope conditions, soil boring tests, soil profile structure tests, vegetation cover, soil erosion observation, offsite water influences, surficial soil sloughing and/or failures and wind, sun and rain exposures. This information needs to mapped and incorporated into a site analysis report and distributed to the project team for review and comments. Site analysis should also include evaluation of rainfall patterns (size and frequency to identify the depth of incorporation). This analysis needs to include a Landscape Architect, Geologist and Engineer experienced in historical rainfall analysis and Soil Structure Engineer to evaluate existing site conditions and adapt and modify the *SRE Concept* so the projects goals and objects are accomplished.

10.3 Geotechnical Review

It is recommended by the *SRE Pilot Study* geotechnical consultant that, in some severe cases, the implementation of the *SRE System* on sloping terrain with potentially adverse geologic conditions may not be prudent because it may affect the surficial stability of the slope, and may affect adjacent structures and improvements. Abandonment of these types of sites should be an option during initial evaluations. However, by conducting an extensive site analysis with the project team most proposed sites can implement an adapted and or modified SRE System which still meets the project goals and objectives. The key to the success for this project is working together with the project team to develop the SRE Concept and yet meet the geological concerns for slope stabilization. It is important to have good communication between the project team members and suggest developing a project checklist of action items and signoffs needed to ensure all project team members approve existing site conditions and recommended amendment incorporation techniques prior to construction to ensure the project goals and objectives are met and the project is safe.

Geotechnical Review will be specific to each project site and should address project opertunities and constraints and address potential treatments related to the development of the *SRE System*. The following is a preliminary outline of suggested guidelines to assist in evaluating the site-specific geotechnical concerns at each project site. This list is not all-inclusive, and the geotechnical consultant responsible for each site may amend these guidelines as they deem appropriate.

1. Existing geotechnical (soils) engineering reports for project sites should be provided to the geotechnical consultant for review. The geotechnical information included in these reports will assist in the understanding of the geologic conditions at a site and is relevant for an evaluation of the proposed *SRE System* implementation activities.

2. Grading plans, if available, for the existing graded slopes that indicate the original slope face gradient/location and the resultant slope gradient/location should be provided to the geotechnical consultant for review and evaluation.

3. The geotechnical consultant should research and review existing geologic maps and literature to assist in acquiring a better understanding of the geologic conditions at a site.

4. Field reconnaissance of the existing site conditions and the existing soils/geologic conditions at a project site is an important component of the geotechnical evaluation of a site. The slope should be logged and adverse geologic factors, such as out-of-slope bedding and joints, should be evaluated. The locations of nearby improvements such as utilities and structures should be considered. The steepness of the slope should be noted and mapped. The presence of groundwater indications and the direction of surface water flow onto the site, if any, should be noted.

5. If the geotechnical consultant deems necessary, geotechnical laboratory testing may be performed on samples of the surficial soils to evaluate pertinent geotechnical engineering parameters.

6. If additional near-surface and subsurface geologic/soils information is desired by the geotechnical consultant, they may propose a subsurface exploration program to better characterize the site-specific geologic and soils conditions.

7. The accumulated data should be analyzed by the geotechnical consultant with respect to the proposed *SRE System* treatment at the site.

8. Discussions with the project team members regarding the site-specific geotechnical concerns and treatment options will be an important task for successful implementation of the *SRE System*. Please note that it may be the opinion of the project geotechnical consultant that surficial stability of a project slope may be compromised by the implementation of the *SRE System* at a particular site and abandonment of the project at that site may be recommended.

9. The geotechnical consultant should be in the field during initial construction to check that the exposed geologic/soil conditions are similar to those assumed from the research and field reconnaissance tasks. In addition, the geotechnical consultant and the project team should discuss the actual field conditions and any equipment limitation concerns. Guidance by the geotechnical consultant may also be helpful as construction tasks progress.

10. After *SRE System* construction at a site is completed, monitoring by the geotechnical consultant should continue to check for indications of potential geotechnical instability.

11. Each task should be appropriately documented. “Lessons learned” from each project site can be applied to future *SRE System* implementation efforts.

10.4 SRE Concept Development

The project team should evaluate existing site conditions and develop an SRE concept for the specific site conditions. The SRE concept provides the treatment recommendations for remediation of construction-impacted soils so that they can be sustainably revegetated and reduce storm water runoff. This concept memo will identify and recommend soil amendments, amendment incorporation requirements, geological repairs, site constraints, landscape planting and erosion control to assist in the design development and construction installation. Suggest providing or adding information regarding supplemental watering to ensure proper plant establishment and additional follow up seeding and or planting after the first year to ensure that the project gets established to the proper vegetation level desired.

10.5 Construction Implementation Recommendations

Highly recommend having a preconstruction site meeting with construction staff and project team to go over existing site conditions and implementation methods of amendment incorporation to ensure the *SRE* concept goals and objectives are properly achieved to the satisfaction of the project team while maintaining the structural stability of the project slopes. Also at this time, the project team needs to review proposed amendment incorporation techniques prior to construction. All questions and concerns by team members need to be addressed and resolved to ensure compliance with the project goals and objectives and that the project is safe and secure.

The following is an outline of suggested future construction incorporation techniques created and developed from the observations and lessons learned during the development of this *SRE Pilot Program.*

10.5.1 Site Preparation

Whether it is a new site or a modification to an existing site we highly recommend implementing a weed control program prior to construction installation. Each project site should be cleared of invasive weeds and grasses by manual or mechanical methods. All grasses and shrubs to be removed or cut to the ground. All cuttings and debris should be removed from the site and disposed of in an appropriate dump site. Also recommend having a 30-day grow kill program performed to remove all weeds and new growth prior to construction. Also recommend providing routing weeding of the site for the first two years until the project vegetation is properly established.

10.5.2 Soil Amendment

All of the treatment sites used a woody compost blend as a soil amendment, which was placed on the soil surface and incorporated into the soil using various mechanical incorporation techniques. The rate of amendment and the ratio of screened compost to woody shreds will vary per site and conditions. The amount of screened compost should reflect the needs of the soil and the potential for establishing unwanted weeds. Incorporation of woody, organic amendments such as yard waste compost provides for increased infiltration, easier rooting for plant material and provides a blend of nutrients for a wide range of soil and plant growth conditions.

The typical blends of screened compost and wood shreds consist of 50:50 or 25:75 yard waste compost screened to 10mm (3/8 inch minus) and woody shredded material (6 inch minus). This material can be obtained as a single blended material or obtained separately. Material can be blended on site as was done at ED 49-Coloma or can be applied separately in two separate applications as done at Templin highway. There can be difficulty in finding and purchasing material, especially locally that meet the specification of the bended material and therefore purchasing material separately and mixing on the site may be easier and more cost effective. Recommend using shredded material preferred to chips because they will last longer and provide better edges and spaces for water retention and plant roots to enter.

10.5.3 Soil Amendment Incorporation Techniques

Typically the goal of the *SRE* strategy is to 1) incorporate organic amendments 12-24 inches into the soil to improve water infiltration, nutrient availability and rooting depth to improve the conditions in the root zone for plant growth and 2) perform deeper ripping (3-4 feet) over portions of the site for sustainable watering infiltration, retention and storm water benefits, as well as for sustainable rooting. Typically the project site shall be covered with a blanket of amendments (2-4 inches deep), consisting of a mix of compost and woody shreds, that are blended into the soil profile. Recommend varying depts. of incorporating soil amendments into the onsite soils profile to avoid a slip plane and also provide additional fracturing of the soil profile up to a depth of 4 feet. This will allow needed soil amendments for quick establishment of plant material and additional fracturing of soil profile for water infiltration. The following are various recommended soil amendment incorporation techniques that were quite effective in achieving the amendment incorporation to the satisfaction to the project team. These techniques also are very cost effective and could be easily completed as part of a new roadway project or modification to an existing site.

Technique #1 Initial Deep Ripping
(Recommended for project slopes 2:1 or Less in steepness)

For initial amendment incorporation and deep fracturing of the soil profile to a depth of 4 feet we found using a D-6 Caterpillar track dozer with 36-inch long ripping teeth spaced 36 inches apart easily ripped and fractured the onsite soils and incorporated the amendments into the soils. The ripping generally consisted of the equipment passing one time across the project site creating ripping patterns approximately 3 feet apart, roughly parallel to the toe of the slope. This method deeply breaks up the soil profile 3' to 4' deep allowing better water infiltration and incorporates soil amendments into the soil profile. However, this method did not completely blend the amendments thoroughly enough into the soil profile as required by the project team and additional mixing and incorporation of amendments were needed in the upper 24" inches of the soil profile. Therefore this method should be supplemented with an additional method to properly mix the amendments within the upper 24 " inches of the soil profile to obtain the proper incorporation blend as outlined in the SRE Concept.

Technique #2 Additional Amendment Mixing and Incorporation
(Technique used to supplement technique #1)

Depending on the site conditions additional methods of incorporation may be needed to provide better incorporation and blending of the soil amendments into the top 18 to 24 inches of the soil profile. During the development of this program we found two different types of additional amendment mixing and incorporation techniques which were very successful and cost effective to implement. The first additional soil amendment mixing and incorporation technique is recommended for slope less than 2:1 and greater than 4:1 and consisted of using a D-6 Caterpillar track dozer which passes, roughly perpendicular to the toe of the slope and excavates in an undulating manor the surficial soils by raising and lowering the blade as the dozer progresses up the slope face. The resultant excavated slope areas should be approximately 2 to 3 feet deep and spaced approximately 8 to 10 feet apart. This method will efficiently mix and incorporate the amendments into the soil profile to the recommended 2 to 3 foot depth as desired by the project team. During the descents, the dozer lowers it's blade and smoothes the slope surface back to its original configuration which provides additional soil amendment incorporation. Subsequently, the slope face should be track-walked one time passing up and down the slope by the D-6 Caterpillar track dozer to recompact the surficial soils to a minimum level acceptable by the geotechnical consultant. This technique is very effective and quickly mixes and blends the amendments into the soil profile.

The second additional amendment mixing and incorporation technique is recommended for slopes less than 4:1 and uses a skip loader with a grading attachment and 18 inch ripping teeth. This technique uses a skip loader to cross ripe the entire site using the grading ripping teeth to mix and incorporate the amendments throughout the soil profile. The skip loader then conducts a final pass over the site to flatten the larger rows with the grading attachment and finishes the soil surface with small 4-inch furrows that are horizontal to the bottom of the slope. These 4-inch furrows act as diversions to eliminate potential negative effects of downslope surficial water runoff. This method is very efficient at incorporating amendments into the soil profile and finishing the site surface.

Technique #3 Shallow Surface Amendment Incorporation
(Recommended for project slopes with unstable slopes and or slopes over 2:1 in steepness)

Because project site conditions can very certain projects may have to limit the amendment incorporation depth into the soil profile because of possible adverse conditions to the stability of the project slopes. These instances are typically for slopes over a 2:1 steepness and or for slopes with geological conditions that might destabilize existing slopes if significantly disturbed. For these types of areas minor incorporation of amendments into the soil surface may still be feasible under the direction and supervision of the project team as long as it does not destabilized the existing site slopes.

A successful shallow surface technique was developed which incorporated the soil amendments into the soil profile to an approximate depth of 4 to 6 inches below the ground surface. This incorporation was accomplished by placing the compost and mulch over the entire site and the using an excavator with a 3 foot wide bucket to loosen and scrape a few inches of the shale and mix it in place with the site amendments to create a surficial surface amended soil profile. This technique worked well and was done in a production like manor and created a nice 4 to 6 inch amended soil structure with out destabilizing the existing slope profile.

Technique #4 Localized Deep Amendment Incorporation
(Recommended as supplemental techniques for #3 above or for amending islands for container plantings)

Depending on the project site and existing site conditions, the *Project SRE Concept* may also suggest adding additional localized deep amendment incorporation methods to provide additional amended areas to improve water infiltration and provide deeper amendment incorporation suitable for planting container plants. This treatment can also be used on very steep slopes or where stability factors limit amendment treatments. In these cases, small amended areas may be created to improve growing conditions that will not destabilize the entire slop. During the development of this program we found two techniques that were very successful and cost effective at doing this additional amendment incorporation.

The first additional localized deep amendment technique used a track excavator with a 3-foot wide bucket to excavate pits that disturb the existing in-place soils and incorporates additional amendments deep into the soil profile. These pits were approximately 6 feet wide and 4 feet deep. The excavated soils then can be amended with compost and mulch and replaced back into the hole and recompacted as per the geotechnical consultant's recommendations. These pits are typically spaced per the geotechnical consultant's recommendations 15 to 20 feet apart in random patterns across the slope face. This technique works well and can be efficiently installed in a production like manor and provided localized areas of deep amendment incorporation.

The second recommended deep incorporation technique uses a 3400 track excavator with an impact breaker attachment to create impact holes in the existing in-place soils by fracturing localized areas on the slope. The resultant impact holes create a 1 foot wide by 3 feet deep hole. This process also causes fracturing of the soils adjacent to the impact points extending approximately 3 feet laterally in all directions from the initial impact hole. These impact holes can then be filled with amended soils which improved water infiltration, reduce erosion and improve plant rooting depths. These impact holes are spaced per the geotechnical consultant's recommendations, typically 5 feet apart in random groups and clusters. Recommend adding a customized attachment to the impact breaker to extend the impact breaker bar which will extend the range of the impact hole from 30 inches in depth to 36 to 48 inches in depth. This will provide localized areas with deeper amendment incorporation which will improve localized plant rooting depths.

10.5.4 Control of Offsite Surface Waters

Storm water runoff from the adjacent upslope properties can cause severe erosion problems for a typical project site. If during the initial site investigation, significant offsite water is deemed to impact project site then mitigation efforts need to be implemented to reduce or eliminate offsite water from impacting the project site. Recommend adding a soil berm or a drainage channel at the top of the slopes to redirect these offsite surface waters away from the project. This will eliminate offsite impacts to the site and protect the existing slopes. The design and location of these control devices shall be recommended in the *Project SRE Strategy*.

10.5.5 **Mulch Material and Application**

Highly recommend addition of woody mulch material be applied to soil surface which will assists in erosion control, increased water infiltration into the soil substrate and provide a protective cover for plant establishment. Apply 2” maximum woody shredded material (6 inch minus) wood mulch to entire planting areas after hydroseeding.

10.5.6 Permanent Erosion Control and Planting Installation

The *SRE Project Concept* will specify permanent erosion control methods that includes hydroseeding of native grasses, forbs and shrubs and may include additional planting of container plants. Prior to any hydroseeding or planting, the project site should have all soil amendments incorporated into the soil profile as outlined in the *Project SRE Strategy*. Once completed project hydroseeding shall be installed. Suggest hydroseeding using a low rate M-Binder and minimum rate of hydromulch. This will ensure seed gets maximum contact with soil surface and will improve seed germination. Once hydroseed is completed top dress entire hydroseeded areas per the *Project SRE Strategy* with a 2 inch layer of mulch. This mulch blanket is applied to protect the hydroseed mix, promote water infiltration, reduce storm water runoff and to help retain soil moisture during plant establishment. Container planting should be installed after applying mulch layer to protect plant material from being damaged during mulch installation. Suggest developing customized plant containers the have plant rooting structures a minimum of 3” inches wide by 9” long. This size plant material will quickly establish root structures into amended soil area and have a better survivability rate as compared to smaller deep cell plant material. Once installation is completed contractor needs to water the entire project using a water truck to establish proper moisture levels for plant germination and establishment until seasonal rains can establish proper soil moisture levels.

10.5.7 Erosion Control Devices

Depending on the project size, slopes, soils and existing site conditions, additional erosion control devices may need to be added to the project to provide additional erosion control until the project is established. The *Project SRE Plan* and project team will decide which additional erosion control devices that will be needed for each specific project based on proposed concept plan and existing site conditions.

Typically for most projects a top dressing of mulch will be added to the entire site surface which will provide adequate erosion control. Recommend adding eight-inch thick straw wattles placed horizontal spaced at 15-foot on center from the foot of the slopes to the top for added erosion control during plant establishment. This additional erosion control device reduces surface water velocity and erosion until project vegetation is established. Once the landscape vegetation cover is established these additional erosion devices can be removed.

Certain sites with steep slopes or with poorly compacted soils may need to have a erosion control blanket installed to help secure loose soils until hydroseed germinates and plant establishment is attained. Recommend using loose weave fiber type erosion control blanket that has plenty of open holes and spaces to allow for plant germination and establishment. Recommend installing erosion control blanket using staples per manufacture's specifications and also adding ¼ " x 24" rebar stakes with rounded ends as necessary to provide additional securing of the blanket to the slope and also at the bottom of the slope to minimize soil erosion.